

5.8 What Is the Ecological Condition of the Entire Nation?

The previous sections asked questions about the ecological condition of forests, coasts and oceans, fresh water ecosystems, urban and suburban areas, farmlands, and grasslands and shrublands nationally. Because ecosystems are hierarchical (O'Neill, et al., 1986) some important questions about ecological condition cannot be answered in terms of these land cover classes. Examples of large-scale issues include the following:

- The relative distribution of forests, grasslands, farmlands, and urban/suburban areas across the entire nation.
- Neotropical migratory birds and other species do not depend on one ecosystem type, but many, often spread over large regions.
- The condition of forest streams, and of other low-order streams across regions, was considered in Section 5.6, but processes in very large watersheds (e.g., the Mississippi or Columbia River basins) reflect the sum total of contributions from many ecosystem types.
- Typically, large systems are slower to change and to respond to management actions (O'Neill, et al., 1986; Messer, 1992). Global climate change and changes in stratospheric ozone are examples of stressors of this type (Rosswall, et al., 1988).

Because EPA's regulatory programs, both alone and in combination, typically impact many kinds of ecosystems, such large-scale questions are an important part of tracking the overall effectiveness of these programs in protecting the entire nation.

Exhibit 5-38 shows the indicators for the entire nation used in this report. All seven of the indicators are taken from the core national indicators in *The State of the Nation's Ecosystems* (The Heinz Center, 2002). There are indicators for four of the six essential ecological attributes with at least regional data, but no indicators on hydrology and geomorphology or natural disturbance regimes with data available on a national or regional level (The Heinz Center, 2002).

Exhibit 5-38: Indicators covering the entire nation

Essential Ecological Attribute	Indicators	Category		Source
Landscape Condition		1	2	
Extent	Ecosystem extent	■		USDA, DOI, DOC
Landscape Composition				
Landscape Pattern/Structure				
Biotic Condition				
Ecosystems and Communities	At-risk native species		■	NatureServe
Species and Populations	Bird Community Index		■	EPA
Organism Condition				
Ecological Processes				
Energy Flow	Terrestrial Plant Growth Index	■		DOI, DOC
Material Flow	Movement of nitrogen	■		DOI
Chemical and Physical Characteristics				
Nutrient Concentrations				
Other Chemical Parameters				
Trace Organic and Inorganic Chemicals	Chemical contamination		■	DOI, EPA
Physical Parameters				
Hydrology and Geomorphology				
Surface and Ground Water Flows				
Dynamic Structural Conditions				
Sediment and Material Transport				
Natural Disturbance Regimes				
Frequency				
Extent				
Duration				

Indicator

Ecosystem extent - Category 2

Extent provides basic information on how much of an ecosystem exists, where it is, and whether it is changing over time. Changes in the extent of various cover types in the U.S. have been driven primarily by human land and water uses over the past 400 years. The total amount and relative distribution of land-cover types at the regional and national level are important, because ultimately they affect many of the ecological attributes such as biodiversity. For example, not only do forest species depend on forests, but many forest species also depend on adjacent wetlands or grasslands.

What the Data Show

Estimates show that before European settlement, the U.S. had 1 billion acres of forests (USDA, FS, 2002), 900 to 1,000 million acres of grasslands and shrublands (Klopatek, et al., 1979) and 221 million acres of wetlands (Dahl, 2000). Today, the U.S. has 749 million acres of forests (USDA, FS, 2002), 861 million acres of grasslands and shrublands (The Heinz Center, 2002), and 106 million acres of wetlands (Dahl, 2000). About 530 million acres of croplands (USDA, NRCS, 2000) and 90 million acres of urban and suburban land uses (USDA, NRCS, 2001) have been added.

The acreage of forest and fresh water wetlands have each declined by about 10 million acres in the decades since the 1950s; the acreage of croplands has fluctuated, but it is currently about 35 million acres less than in the 1950s; and urban areas have grown by 40 million acres during the same period (The Heinz Center, 2002) (Exhibit 5-39).

Indicator Gaps and Limitations

According to The Heinz Center (2002), the National Land Cover Database (NLCD) produced different estimates of area for forests and farmlands from those mentioned above, because of differences in the definitions of these systems in the Forest Inventory and Analysis (FIA) and the USDA Economic Research Service (ERS). In addition, current indicators of extent do not provide information about fragmentation and landscape patterns.

Data Sources

The data sources for these indicators were Forest Inventory and Analysis, U.S. Department of Agriculture (1979-1995); National Land Cover Database, Multi-Resolution Land Characteristics Consortium (1990s); National Wetlands Inventory, U.S. Fish and Wildlife Service (1970-2000); and Economic Research Service, U.S. Department of Agriculture (1982-1997). (See Appendix B, page B-48, for more information.)

Exhibit 5-39: Change in ecosystem extent, long-term and recent trends, 1950s-1990s

Data Not Adequate for National Reporting on Extent of brackish coastal waters

Partial Indicator Data: Long-term Changes for Forests, Croplands, Grasslands/Shrublands, Urban/Suburban



Partial Indicator Data: Recent Trends for Forests, Croplands, Grasslands/Shrublands, Urban/Suburban, Freshwater Wetlands



Coverage: lower 48 states.

Note: Because these estimates are from different sources, they do not sum to 100% of U.S. land area. Approximately 5% of lands are not accounted for by these data sources. They include some wetlands, some non-suburban developed areas, disturbed areas such as mines and quarries and the like. In addition, freshwater wetlands currently occupy approximately 5% of the area of the lower 48 states, a reduction of about 50% since presettlement times. Because they are found within forests, grasslands, and shrublands, or croplands, freshwater wetlands from those ecosystems are shown as aggregated data on the graph. Finally, the "urban" trend line in this graph is based on a different definition from the one in this report and is presented here to illustrate general trends. The definition used in this report was used to generate the "urban/suburban (satellite)" area estimate.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002. Data from the USDA Forest Service (forests, current area, recent trends), USDA Economic Research Service (croplands trends, urban area trends), Multi-Resolution Land Characterization Consortium (MRLC; all satellite data, including current estimate of grass/shrub and urban/suburban area in top graph). Presettlement estimates are from Klopatek et al. 1979.

Indicator

At-risk native species - Category 2

Scientists are engaged in considerable discussion about the importance of rare and at-risk species for the sustainability of ecosystems (e.g., Grime, 1997; Hodgson, et al., 1998; Naeem, et al., 1999; Tilman and Downing, 1994; Wardle, et al., 2000). There are at least 200,000 native plant, animal, and microbial species in the U.S., but according to The Heinz Center (2002), "little is known about the status and distribution of most of these." This indicator represents what is known about 22 species groups, including 16,000 plant species and 6,000 animal species. It includes all higher plants; all terrestrial and fresh water vertebrates (i.e., mammals, birds, reptiles, amphibians, and fish); select invertebrate groups, including fresh water mussels and snails, crayfishes, butterflies and skippers; and about 2,000 species of grasshoppers, moths, beetles, and other invertebrates (The Heinz Center, 2002). The Heinz Center believes that this indicator is a powerful—yet manageable—snapshot of the condition of U.S. species. No data are available for marine species, which led The Heinz Center to rank this as an indicator equivalent to a Category 2. Special groupings of these species have been used as indicators in specific ecosystem categories. This indicator includes all of them, but The Heinz Center has not analyzed species dependent on large or multiple ecosystems.

What the Data Show

One-third of species native species are at risk, and 1 percent of plant and 3 percent of animal species might already be extinct (The Heinz Center, 2002) (Exhibit 5-40). Approximately 19 percent of native animal species and 15 percent of native plant species are ranked as imperiled or critically imperiled. There are large differences among plant and animal groups and among regions. For example, the percentage of at-risk fresh water species such as mussels and crayfish is much higher than that for birds or mammals, and more at-risk species are found in California, Hawaii, the southern Appalachians, and Florida than elsewhere (Stein, 2002).

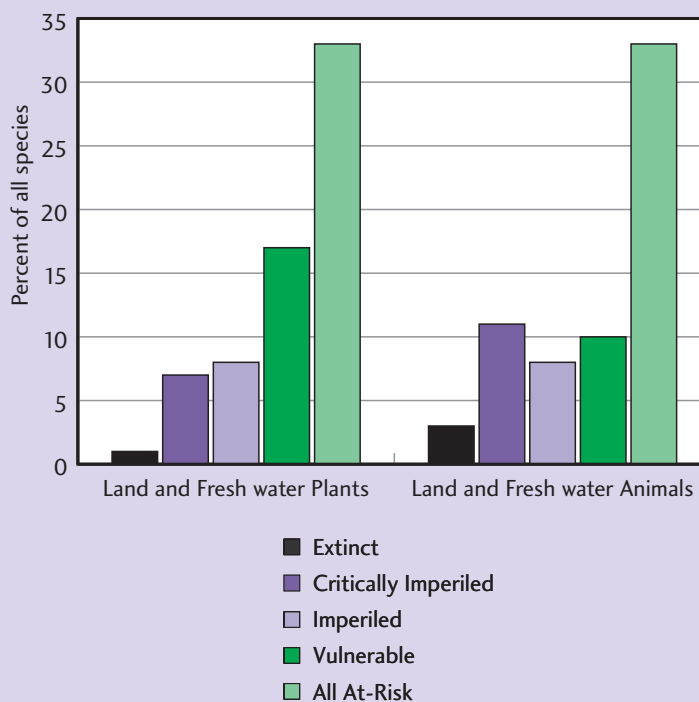
Indicator Gaps and Limitations

The data are from a census approach that focuses on the location and distribution of at-risk species. Therefore, distinguishing trends in the indicator is difficult.

Data Source

The data for this indicator was *The State of the Nation's Ecosystems*, The Heinz Center, 2002, using data from the NatureServe Explorer database. (See Appendix B, page B-48, for more information.)

Exhibit 5-40: At-risk land and fresh water plant and animal native species, 2000



Coverage: all 50 states.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002. Data from NatureServe and its Natural Heritage member programs.

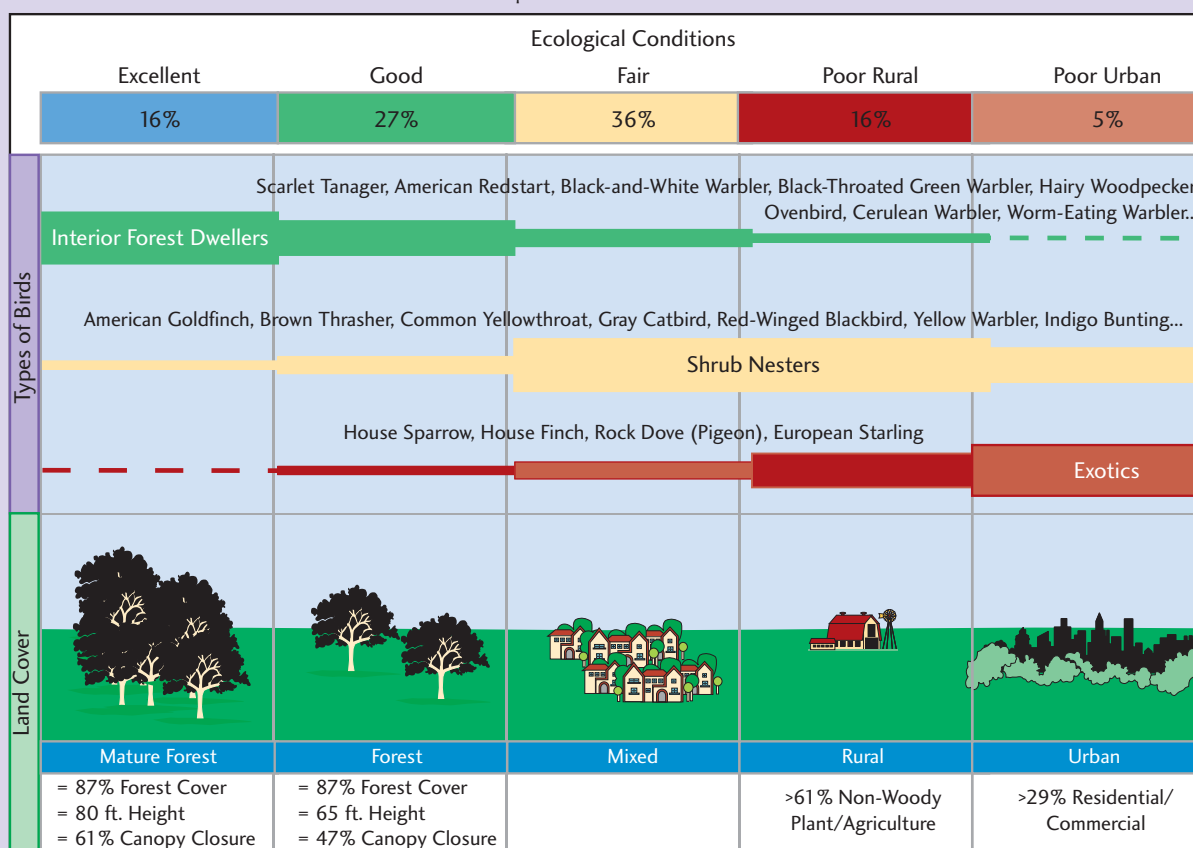
Indicator

Bird Community Index - Category 2

The types of birds observed in an area have been shown to serve as an indicator of the overall characteristics of the landscape. Species vary in their sensitivity to physical, chemical, and biological threats, and different species require different habitats for food, shelter, and reproduction. Some species need extensive areas of interior forest, others prefer the edges between different types of land cover or mixed areas, and still others prefer disturbed or highly managed areas. Consequently, the composition of the bird community reflects the overall mix, pattern, and condition of the mosaic of forest, agriculture, grasslands and shrublands, wetlands, streams, and urban/suburban areas that makes up most of the U.S. landscape.

The Bird Community Index (BCI) was developed by O'Connell, et al. (1998, 2000) for songbirds in the mid-Atlantic states. The index was developed based on data collected at 34 reference sites, with bird species classified into 16 functional groups according to the degree to which they specialized in using the native flora and fauna in an area (high BCI scores) versus being generalists and exotic or invasive species (low BCI scores). The BCI then was applied to a probability sample of bird data from 126 sites across the Mid-Atlantic Highlands.

Exhibit 5-41: Bird species as characteristics of landscape composition and pattern as an indicator of landscape condition, 1995-1996



Coverage: Mid-Atlantic Highlands (Maryland, Pennsylvania, Virginia, West Virginia).

Source : EPA, Office of Research and Development. *Birds Indicate Ecological Condition of the Mid-Atlantic Highlands*. June 2000.

Indicator

Bird Community Index - Category 2 (continued)

What the Data Show

Good-to-excellent BCI scores (diverse communities of birds characterized by many specialists and native species) were associated with at least 87 percent forest cover and a minimum of 47 percent canopy closure. Poor BCI scores (low diversity communities characterized by generalists and exotic species) were associated with either rural agricultural or urban areas where almost 30 percent of the landscape was in residential or commercial land use.

The BCI was calibrated across a range of landscape conditions from least disturbed to significantly degraded. Based on this calibration, 43 percent of the Mid-Atlantic Highlands was estimated to be in good to “excellent” condition (in other words, containing large tracts of interior forest), 36 percent was estimated to be in “fair” condition, and 21 percent (5 percent urban and 16 percent rural) was estimated to be in “poor” condition (Exhibit 5-41). Forested sites in good and excellent condition supported different bird communities and ground-level vegetation attributes, but could not be separated by land cover composition alone. As the proportion of the landscape in forested areas decreased or the proportion of canopy closure decreased, so did the BCI scores (O’Connell, et al., 1998, 2000).

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- This indicator depends on a value judgement common among ecologists that communities associated with the native vegetation of a region are “better” than exotic, generalist species associated with human modification of the environment.
- The BCI has been calibrated and assessed only for the Mid-Atlantic Highlands, and may not apply to areas where shoreline birds or migratory waterfowl are a larger component of the bird community.
- The BCI relates primarily to land cover estimates, and does not explicitly include the condition of any particular land cover type.

Data Source

The data sources for this indicator were *A Bird Community Index of Biotic Integrity for the Mid-Atlantic Highlands*, O’Connell, et al., 1998; and *Bird Guilds as Indicators of Ecological Condition in the Central Appalachians*, O’Connell, et al., 2000, using data from U.S. Environmental Protection Agency Mid-Atlantic Highlands Program and the National Land Cover Database. (See Appendix B, page B-48, for more information.)

Indicator Terrestrial Plant Growth Index - Category I

Both the National Research Council and Science Advisory Board reports suggest that primary productivity (the amount of solar energy captured by plants through photosynthesis) is a key indicator of ecosystem function (NRC, 2000; SAB, 2002). Generally, ecosystems will maximize their primary productivity through adaptation (Odum, 1971), so primary productivity can increase under favorable conditions (e.g., increased nutrients or rainfall) or decrease under unfavorable conditions (e.g., plant stress caused by toxic substances or disease). Changes in primary productivity can result in changes in the way ecosystems function, in the yield of crops or timber, or in the animal species that live in the ecosystems.

Gross primary productivity is related to the standing crop of the photosynthetic pigment chlorophyll and can be thought of in simple terms as plant growth. The Terrestrial Plant Growth Index indicator is based on the Normalized Difference Vegetation Index (NDVI), which measures the amount of chlorophyll, using satellite data (The Heinz Center, 2002). While the standing crop of chlorophyll is not identical to primary productivity, EPA's Science Advisory Board (EPA, SAB, 2002) lists it as an example of an indicator under the ecological processes EEA.

What the Data Show

No overall trend in plant growth is observed for the 11-year period from 1989 through 2000, for any land cover type or any region of the U.S., although year-to-year measurements can fluctuate by up to 40 percent of the 11-year average (The Heinz Center, 2002) (Exhibit 5-42). Over a sufficiently long period, regional trends in NDVI could be an important indicator of increasing or decreasing plant growth resulting from changing climate, UV-B exposure, air pollution, or other stressors.

Indicator Gaps and Limitations

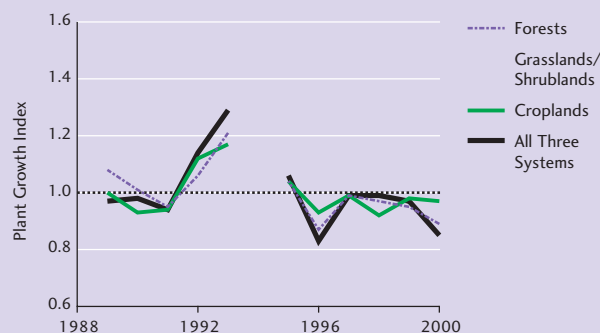
There were no calculations for phytoplankton or submerged vegetation growth in fresh water or coastal systems.

Data Source

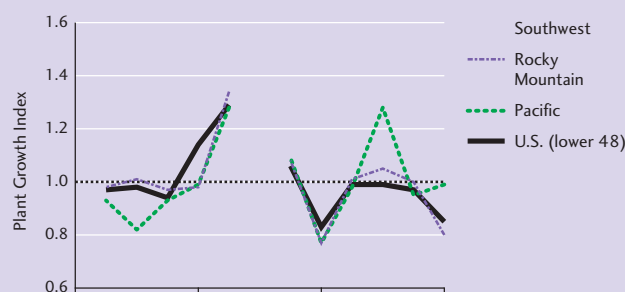
The data source for this indicator was *The State of the Nation's Ecosystems*, The Heinz Center, 2002, using data on visible and near-infrared wavelengths collected by the National Oceanic and Atmospheric Administration's Advanced Very High Resolution Radiometer and converted into a Normalized Difference Vegetation Index (Reed and Young, 1997). (See Appendix B, page B-49, for more information.)

Exhibit 5-42: Plant Growth Index, 1989-2000

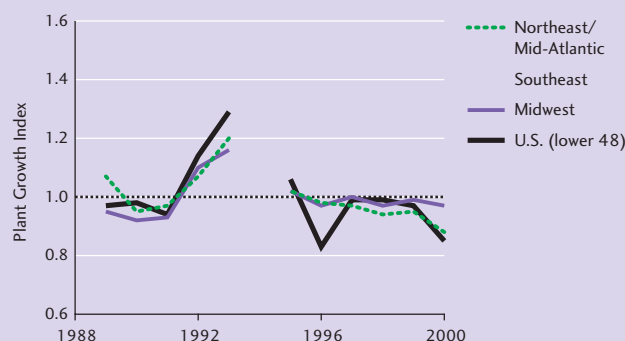
Terrestrial Plant Growth Index for lower 48 states



Plant Growth Index: southwest, rocky mountain, pacific regions



Plant Growth Index: northeast, southeast, midwest regions



Coverage: Lower 48 states.

Note: Because of satellite problems, no data are available for 1994.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002.

Data from the U.S. Geological Survey; Multi-Resolution Land Characterization Consortium.

Indicator

Movement of nitrogen - Category I

Nitrogen is a critical nutrient for plants, and “leakage” of nitrogen from watersheds can signal a decline in ecosystem function (Vitousek, et al., 2002). It also may signal the failure of watershed management efforts to control point, non-point, and atmospheric sources of nitrogen pollutants, and the resulting nitrogen may have “cascading” harmful effects as it moves downstream to coastal ecosystems (Galloway and Cowling, 2002). Nitrate concentration in streams has served as an indicator of chemical condition in the other ecosystems in this section. This indicator, however, deals with nitrogen export from large watersheds, and is an indicator of ecosystem function.

What the Data Show

Nitrate export from the Mississippi River has been monitored since the mid-1950s and from the Susquehanna, St. Lawrence, and Columbia Rivers since the 1970s, and is reported in *The State of the Nation's Ecosystems* in tons per year. The load in the Mississippi River has fluctuated from year to year, but it has increased from approximately 250,000 tons per year in the early 1960s to approximately 1,000,000 tons per year during the 1980s and 1990s (The Heinz Center, 2002) (Exhibit 5-43). The Mississippi River drains the agricultural “breadbasket” of the nation and contains a large percentage of the growing population, so the increases likely reflect failure to control nitrogen pollution, rather than a breakdown in ecosystem function (e.g., Rabalais and Turner, 2001). Nitrate loads in the other three rivers have fluctuated around 50,000 tons per year since the 1970s, although the Columbia River spiked to 100,000 tons per year in the late 1990s.

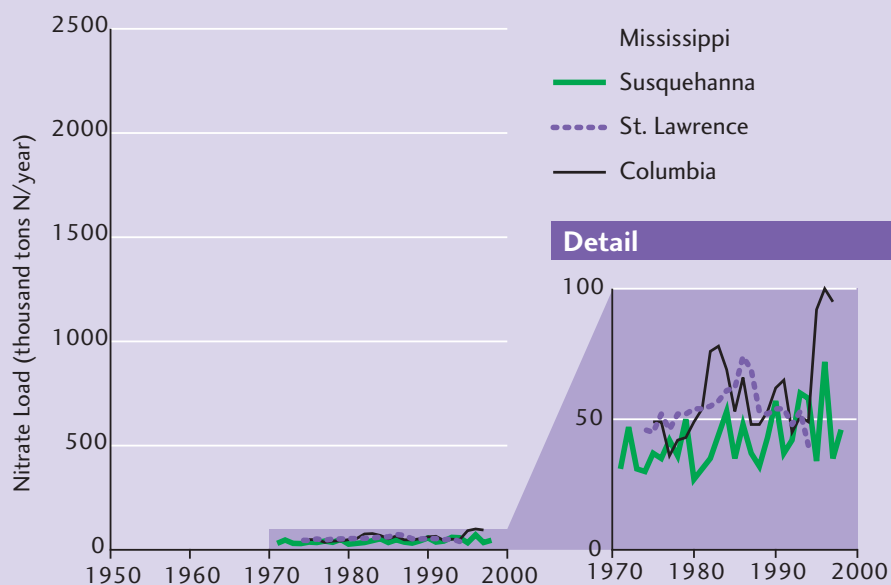
Indicator Gaps and Limitations

The indicator does not include data from numerous coastal watersheds whose human populations are rapidly increasing and are therefore estimated to have high nitrogen loss rates (e.g., Valigura, et al., 2000). It also does not include other forms of nitrogen besides nitrate, which may constitute a substantial portion of the nitrogen load.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems*, The Heinz Center, 2002, using data collected by the U.S. Geological Survey, National Stream Quality Accounting Network and National Water Quality Assessment Program, and by the U.S. Army Corps of Engineers. (See Appendix B, page B-49, for more information.)

Exhibit 5-43: Nitrate load carried by major rivers, 1970-1999



Coverage: selected major rivers.

Source: The Heinz Center. *The State of the Nation's Ecosystems*. 2002.

Data from the U.S. Geological Survey's National Stream Quality Network (NASQAN), National Water Quality Assessment (NAWQA), and Federal-State Cooperative Program.

Indicator

Chemical contamination - Category 2

This indicator has been discussed for the individual ecosystems, but here it is reported for all media, regardless of land-cover type. The following is a summary of the key findings; the Heinz report (2002) should be consulted for further details.

What the Data Show

Three-fourths of all streams in the National Water Quality Assessment (NAWQA) network had one or more contaminants that exceeded guidelines for the protection of aquatic life, and one-fourth had four or more contaminants over those levels. One-fourth of ground water wells sampled had one or more contaminants above human health standards. One-half of all streams had one or more contaminants in sediments that exceeded wildlife protection guidelines (usually more stringent than criteria to protect human health). One-half of all fish tested had one or more contaminants that exceeded wildlife protection guidelines. Approximately 60 percent of estuarine sediments tested had concentrations of contaminants expected to lead to "possible effects" in aquatic life, and 2 percent had concentrations exceeding levels expected to have "likely effects."

Indicator Gaps and Limitations

The limitations of this indicator include the following:

- While these data represent a comparison of a standard to the respective contaminant concentration, they do not represent assessments of risk posed to humans or ecosystems.
- Different standards also reflect different levels of protection, so these data should be interpreted cautiously.
- Media contamination, such as water or sediment contamination, does not necessarily indicate exposure to the contaminant for either humans or other biological populations.

Data Source

The data source for this indicator was *The State of the Nation's Ecosystems*, The Heinz Center, 2002, using data from the National Water Quality Assessment Program and the Environmental Monitoring and Assessment Program, Estuaries Program. (See Appendix B, page B-50, for more information.)

Summary: The Ecological Condition of the Entire Nation

The idea of monitoring indicators that could include the entire nation, irrespective of the type of land cover, has not been a main topic of ecological monitoring. The main idea is that pressures acting over large areas may have effects that transcend a land cover type, or may depend on the interaction of land cover types. The issue of scale has not been well-articulated with respect to these indicators (issues of national scope may not operate at national scales). This is an area of attention for future reports.

Landscape condition

The National Land Cover Database (NLCD) now provides a consistent national picture of the extent of the various ecosystem types at 30 meter (about 100 foot) resolution (Vogelmann, et al., 2001). A consortium of federal agencies performs the interpretation of the satellite data necessary for development of the NLCD. Much of the data in this indicator come from the Forest Inventory and Analysis (FIA) or the National Resources Inventory (NRI), which allows trends to be estimated during periods prior to the first NLCD coverage. Unfortunately, these data are not comparable to the NLCD, because of differences in the definitions of the land cover categories (see Chapter 3, Better Protected Land).

Biotic condition

With respect to the at-risk native species indicator, the NatureServe database is an invaluable resource for identifying these species. Because the resulting data are developed without an underlying statistical design, however, it will be difficult to determine whether future trends are the result of more thorough field work and reporting by researchers and resource managers, or actual trends in the number of at-risk species. An effort has begun to identify all species in the Smoky Mountain National Park (Kaiser, 1999), and an international effort, called Species 2000, is being developed by a multinational project team associated with the United Nations (U.N.) Convention of Biological Diversity. Recent research expanding the bird diversity index to the entire mid-Atlantic region shows that it has promise as a national indicator (O'Connell, et al., 2002). Analysis of the biological data from the first 20 National Water Quality Assessment (NAWQA) study units, and similar analyses of Environmental Monitoring and Assessment Program (EMAP) data from the national estuaries and streams in the West and Midwest, should shed some light on the feasibility of a national indicator for estuarine and stream benthic communities. Because the plankton communities of lakes do not exhibit a high degree of biogeographical variation (independent of natural factors such as hardness or the presence of organic color), a national plankton index would seem feasible if the necessary data were collected.

Ecological processes

The *Terrestrial Plant Growth Index* is probably the best example of the indicator of primary productivity called for by both the NRC (2000) and SAB (2002). Comparable data exist on trends for a decade, with census coverage (at the resolution of the AVHRR sensor) for the conterminous U.S. Examination of the trends data for this indicator in The Heinz Center (2002) report shows large (± 40 percent) excursions from the 11-year average in the Southwest, and ± 20 percent excursions in the Pacific region. The amount of time necessary to separate changes caused by air pollutants (e.g., ozone, nitrogen deposition, carbon dioxide) from those caused by natural climatic factors and insect and disease outbreaks is unknown.

The *Movement of Nitrogen* indicator certainly captures trends in this important nutrient in the nation's largest river basins. The indicator would be improved if it included total nitrogen, including an accurate estimate of nitrogen carried in the bed load of sediments as it moves into coastal waters, and if it were extended to the many smaller coastal watersheds that are experiencing large increases in population. An indicator of sediment runoff potential would be a useful large-ecosystem indicator if it were extended to non-farmland ecosystems (see Chapter 3, Better Protected Land).

Chemical and physical characteristics

The *Chemical Contamination* indicator raises a serious question about how representative the streams in the NAWQA study units are. There were 119 NAWQA sites with surface water monitoring data, located in 20 geographically well-dispersed watersheds across the U.S. Eventually, NAWQA plans to expand to 60 such units, and presumably all will include water sampling. On a national basis, this might be an adequate number to represent the range of factors affecting ecological condition of the streams and watersheds. The number of streams characterizing forest, farmland, or urban/suburban watersheds seems too small, however, given the very wide range of nutrient and contaminant concentrations presented in the Heinz report.

More important, however, is whether the streams sampled are representative of the range of streams in the entire nation. The ecological condition of fresh waters (and their watersheds) reflects the sum total of natural factors (including disturbances), conscious and unconscious decisions about land-use management (e.g., what crops to grow, whether and when to cut timber, urban planning and zoning), and the presence and control of pollutants. A particular stream might be representative of a watershed with respect to geomorphology and hydrology, and even land use (e.g., corn or tree farming, urban or suburban). But resource management decisions and the presence or control of pollutants are particular to a specific watershed, and so the streams must be chosen to be representative of the full range of possibilities, and of their relative frequencies. With respect to pollution control, assuming that the full set of environmental controls are working as envisioned by EPA is particularly risky. In fact, this risk is one of the primary reasons for monitoring

progress toward national goals under GPRA; to determine if the programs, as implemented and enforced by the states are really protecting and restoring the biological integrity of fresh waters. In this context, identifying representative streams or watersheds is not as reasonable as identifying representative samples of streams or watersheds. Until the NAWQA streams can be compared to a statistically representative sample of streams, great care must be taken in assuming that the data accurately reflect the national condition of fresh waters and watersheds.

There were no Category 1 or 2 indicators available for this report for *hydrology and geomorphology* or *natural disturbance regimes*, but developing them does not seem to be a particularly daunting challenge, given the widely available data on geology, flow, and paleological methods to indicate the regional occurrence of climatic events and fire.